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PROCEEDINGS
OF THE
AMERICAN PHILOSOPHICAL SOCIETY
HELD AT PHILADELPHIA
FOR PROMOTING USEFUL KNOWLEDGE

A POSSIBLE EXPLANATION OF UPPER EOCENE
CLIMATES.

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(*Read April 21, 1922.*)

No single problem has awakened more interest among geologists and botanists than the climatic significance of the fossil floras discovered in Arctic lands. This interest, although losing some of the zest of novelty, has remained unabated since the first announcements by Professor Heer nearly two generations ago, down to the present. A great variety of hypotheses have been advanced to explain their apparent anomalous distribution. These range all the way from Neumayr's naïve suggestion that organisms have completely changed their environmental requirements during the ages to the thesis recently advanced by Knowlton¹ that Cretaceous and Tertiary climates, as well as those of earlier geologic periods, were controlled by earth heat, and were not subject to solar control, as they are at the present time.

Everyone will, I think, admit that the faunal and floral evidence throughout the major part of geologic time, in so far as it is known, indicates a greater uniformity of climatic conditions and less contrast between high and low latitudes than exists at the present time. There are few, however, who will deny that there were contrasts at all times between high and low latitudes. Throughout most of known geologic time climatic zones appear less marked than now, and I believe that we can rely on the validity of appearances on this point. There are, however, several times in the past when climatic zones were sharply marked, and all of these were at times of land extension and sea

¹ Knowlton, F. H., *Geol. Soc. Amer., Bull.*, Vol. 30, pp. 499-566, 1920.

restriction, as shown by the recurrent periods of glaciation, beginning in pre-Cambrian time, of which that of the lower Permian was more extensive than that of the familiar Pleistocene.

Climatic zones may also have been marked during the times of land emergence, when marine deposits were largely withdrawn from the area of the present land surface of the globe, which events have in general furnished the basis for what are regarded as the systemic rock and time boundaries of geology. If this possibility could be proved it would help to explain the numerous examples of extinction and evolution that emphasize the geologic time table, and it would obviously leave few available marks in the record of life or in the sediments now available for study.

I have always been intensely interested in this subject, as who has not? Circumstances have, however, kept me rather fully occupied with the Mesozoic and Cenozoic floras of lower latitudes. Recently, in working up some Eocene floras for the Geological Survey of Canada—a subject which I approached while fresh from work on the middle and upper Eocene floras of southeastern North America—I was much impressed with the total dissimilarity between these Canadian floras, which are a part of the so-called Miocene² Arctic flora of Alaska, Greenland, Iceland, Spitzbergen, etc., and the contemporaneous flora of our Gulf states. This led to a general survey of the subject, some of the results of which are presented in the following notes.

It may be mentioned parenthetically that both paleozoölogy and paleobotany have suffered the drawbacks incident to the fact that their chief cultivators have been resident in the North Temperate Zone. I do not recall a single paleobotanist who has had a first-hand acquaintance with the tropical floras of the present. The same statement is to a very great extent true of paleozoölogists, and I gravely question whether those who cultivate the field of invertebrate paleontology concern themselves greatly with the results of recent researches in oceanography and their bearing on problems of distribution in the past.

After seeing the sub-tropical existing flora of southern Florida, the tropical flora of the Antilles and Central America, and the tropi-

² Generally recognized to be of upper Eocene age in recent years.

cal, sub-tropical, and temperate rain forest floras of South America, I am convinced that no known fossil flora of Cretaceous or Tertiary age in the United States can properly be called tropical in any but a most loose and uncritical use of that term. Much less can it be applied to the Arctic Tertiary floras. It is true that many of these fossil floras indicate warmer climatic conditions than prevail at the present time in the same latitudes, and it is also true that many of their elements have a seemingly unusual latitudinal range.

Most temperate rain forests of the present would have been pronounced "tropical" by paleobotanists if they occurred as fossils, and I have repeatedly called attention to the resemblance of our Atlantic Coastal Plain Upper Cretaceous floras to temperate rain forests, in which the same mingling of types is observed.

Most of the familiar plants that are enumerated in fossil floras as being of especial, that is, tropical climatic significance, belong to large genera whose species have a wide range and have become adapted to a variety of habitats. Take, for example, palms, which, in my experience in the Yungas of Bolivia, stick closely to the tropical and sub-tropical altitudinal zones; and we find some modern species, incidentally very similar to a great many fossil species, ranging northward as far as North Carolina, and southward as far as Valparaiso, Chile. Another type frequently mentioned in fossil floras is the cinnamon or camphor tree—the two most romantic names applied to two of the many existing species of the genus *Cinnamomum*. The modern species range well into the temperate zone; in fact, the commercial supply of camphor comes largely from Formosa and Japan, the tree being hardy as far north as about Latitude 35° in the latter country with its oceanic climate. Introduced into Florida, *Cinnamomum* has been seeded pretty widely by birds, and is perfectly hardy as far north as Tallahassee in that state.

Tree ferns constitute a third item in the paleobotanist's tropical repertoire, although the most magnificent modern tree ferns are found in temperate rain forests, such as those of New Zealand, on high peaks in the tropics (above the tropical altitudinal zone), or in the montaña valleys of the Eastern Andes (above the tropical altitudinal zone). The bread fruit is another spectacular fossil, and although

the modern species in nature appear to be confined to tropical and sub-tropical environments, fossil forms are found in association with temperate types, as, for example, in the Upper Cretaceous of Greenland, the early Eocene of the Rocky Mountain region and Gulf states, and the lower Miocene of Florida (it is obvious that the advocates of former torridity can exactly reverse the bread-fruit argument), so that one must use considerable caution in any attempt to interpret its meaning in terms of climate.

It may be remarked parenthetically that I do not consider *Aphlebia* as indicative of heat, but humidity. That *Ginkgo* is not a tropical type, but appears to be hardy throughout the Temperate Zone, and does not flourish under cultivation in the Tropics. That Cycads and Conifers are not good criteria for either moist or sub-tropical climates, but quite the reverse. That *Gleichenia* and its present-day segregates, although commonly found in the Equatorial Zone at the present time, are not limited to the tropical part of that zone, but are frequently more at home in the sub-tropical or temperate altitudinal zones in Equatorial uplands, as in Hawaii, the Eastern Andes, etc.

Doubtless terrestrial plants are better indices of climate than are other organisms, and they are admittedly more important in this respect than marine forms of life. Plant fossils have this merit aside from any question of botanical identification, and this feature seems to have been lost sight of by numerous critics of paleobotanical practice: that the size and form of leaves, their texture, the arrangement and character of their stomata, and the seasonal changes in wood, afford criteria that are quite as valuable climatically even though the species or genus to which they belong remains undetermined. Without venturing further on the sea of words that constitutes the elusive generalities of most discussions of past climates, I propose to contrast the Tertiary "Arctic flora" with that which existed contemporaneously in lower latitudes, after which I will suggest a possible explanation to account for the observed facts.

The exact age of this "Arctic flora" can not be conclusively proven, but it is a reasonable assumption that it is of approximately the same age wherever found, and this assumption rests on actual community of composition, and not on an environmental premise,

although there is also something to be said for the latter. Heer studied these Arctic floras after his monumental work on the Tertiary floras of Switzerland, and he called them Miocene, a fashion that still persists in some quarters. It is lost sight of that Heer was prone to see his familiar Swiss Tertiary species in what were often very imperfect fragments from the far North; and it is also true that Heer recognized no Oligocene period, but included the fossils of this age in the Miocene, which, to that extent, never meant more than "old Miocene"—that is to say, Oligocene.

The "Arctic Miocene" flora is certainly younger than that of our Fort Union of the western United States and Canada, whose facies continues into the Wasatch of the same region. It is overlain in places by marine Miocene strata, and interbedded with upper Eocene marine faunas, as at Herendeen Bay, Alaska. I have been inclined to consider it as also younger than the Green River flora of the western United States, and to be of approximately the same age as the Jackson flora of the southern Atlantic Coastal Plain. It is certainly older than any known lower Miocene flora of the United States or Europe, and the following comparisons do not suffer any diminution of conclusiveness, if the Arctic flora should eventually be proven to be slightly older or slightly younger than the Jackson, for we now know as considerable floras in the southern Coastal Plain from the immediately antecedent Claiborne group, and from the immediately subsequent Oligocene (Catahoula and Vicksburg), and all of these have substantially the same facies and climatic significance as has the flora of the Jackson group.

The Jackson flora, a detailed account of which is in press as Professional Paper 92 of the United States Geological Survey, contains considerably over one hundred species. These represent genera such as *Acrostichum*, *Pistia*, *Canna*, *Thrinax*, *Phœnicites*, *Engelhardtia*, *Momisia*, *Ficus*, *Coccolobis*, *Pisonia*, *Myristica*, *Anona*, *Inga*, *Cassia*, *Bauhinia*, *Sophora*, *Lonchocarpus*, *Fagara*, *Cedrela*, *Banisteria*, *Burserites*, *Cupanites*, *Dodonæa*, *Grewiopsis*, *Bombacites*, *Ternstræmites*, *Cinnamomum*, *Mespilodaphne*, *Nectandra*, *Rhizophora*, *Terminalia*, *Conocarpus*, *Conbretum*, *Myrcia*, *Calocarpum*, etc. There is not a distinctly temperate type among them and this flora comes as near meriting the term "tropical" as any fossil flora known from the

Temperate Zone. I regard it, in fact, as sub-tropical. Space does not permit a discussion of the range of the existing representatives of this Jackson flora. This is done in the publication cited above, and the generic names mentioned will serve those of my botanical readers who wish to check my conclusions. Now, let me compare this Jackson flora with the so-called Kenai flora of Alaska.³

The Kenai flora, as published, consists of about 120 species. The most abundant forms are willows, oaks, poplars, walnuts, beeches, birches, hazels, and alders—distinctly Temperate, and cool rather than warm Temperate types. Perhaps the most abundant plants individually, certainly the widest ranging geographically in northern latitudes (Holarctica), are the leaves of hazel bushes (*Corylus*). Of the 54 genera of Knowlton's list, the following nine are not present in the existing flora of North America: *Ginkgo*, *Glyptostrobus*, *Taxites*, *Hedera*, *Paliurus*, *Elæodendron*, *Pterospermites*, *Trapa*, and *Zizyphus*.

It may seem that I am juggling the evidence in omitting these nine genera from further consideration, but let me point out that the three of these about which there seems to be no doubt regarding their identity, namely, *Ginkgo*, *Trapa*, and *Glyptostrobus*, are all Temperate types in the existing flora. The remaining six genera are under more or less suspicion of quite a different order from any differences of opinion among paleobotanists regarding the identification of the hazels, birches, alders, etc., with which they are associated. Opinion might differ as to whether a particular species of the latter was a *Betula* or *Alnus*, an *Ulmus* or a *Carpinus*, or a *Planera*; or whether one or several species of *Corylus* should be recognized as distinct species; but opinion is unanimous that the choice is thus narrowed, whereas in the case of such things as *Taxites*—all any one knows is that it represents some Conifer. Why waste time trying to explain the climatic significance of *Paliurus*, a mostly extinct genus, when the particular fossil is probably not a *Paliurus*; or why concern oneself with an Arctic species of *Zizyphus* when the form in question is probably a *Ceanothus*? I ask, can any one prove that the form-genus *Ptero-*

³ As listed by Knowlton in 1919. Hollick's extended labors on this flora which may be expected to contain some new species, will undoubtedly modify, but will not alter the force of the present comparison.

spermites is genetically related to the existing genus *Pterospermum*? or that *Elæodendron* is a sound botanical identification? I think not!

On the other hand, the great mass of not only the Kenai but of all the Arctic Tertiary floras are the readily recognizable, normal units of a natural assemblage, which individually leave but slight room for differences of opinion regarding their identity. If fruits chance to be found in association with the leaves, they are such things as birch or alder cones, never the fruits of the "suspects" above mentioned.

Of the remaining genera listed in the Kenai flora, all but the following six are represented in the existing flora of Canada: *Æsculus*, *Diospyros*, *Ficus*, *Liquidambar*, *Sequoia*, and *Taxodium*. It may be said of these that the *Æsculus* may not be an *Æsculus*, but a *Hicoria*; that the two species that have been referred to *Ficus* do not belong in that genus; and that *Sequoia* is on the verge of extinction at the present time and its modern range bears little relation to its former range. The case of *Sequoia* is of especial interest in its bearing on my thesis. Formerly a *Holarctic* type, it survives today in a most restricted area particularly favored by humidity.

The remaining genera of the Kenai flora appear to be determined with reasonable certainty. Not only are 39 of these represented in the existing flora of Canada, but the following are still represented in the existing flora of Alaska, or adjacent areas in northwestern Canada, or as far north as Labrador and Hudson Bay in eastern Canada: *Abies*, *Acer*, *Alnus*, *Alnites*, *Andromeda*, *Betula*, *Carex*, *Corylus*, *Equisetum*, *Fraxinus*, *Myrica*, *Osmunda*, *Phragmites* (grass), *Picea*, *Pinus*, *Populus*, *Prunus*, *Pteris*, *Quercus*, *Sagittaria*, *Salix*, *Spiræa*, *Thuites*, and *Vaccinium*.

Seventeen of the Kenai species are Conifers, and the only types that would seemingly be out of place in a cool-Temperate climate with well-distributed moisture are *Liquidambar*, *Paliurus*, *Taxodium*, and *Zizyphus*. I have already given reasons for discrediting the determinations of some of these, and all of them have frequently been found fossil in Temperate assemblages.

The most diversified Arctic Tertiary flora known is that described by Heer from western Greenland. As considerably over-elaborated by Heer it comprises 282 species. Of this number there are 8 worth-

less objects described as fungi; there are 20 ferns; 28 conifers; 21 monocotyledons, of which most are fragments of grass- or sedge-like leaves, generically and specifically undeterminable. Among the monocotyledons are two nominal species of *Flabellaria*—a form-genus proposed for undeterminable palm fossils. Neither of these is very convincing, and if they are correctly figured by Heer I would never think of calling them palms, and yet every textbook speaks of the Tertiary palms of Greenland, although they always have been purely subjective.

The bulk of the Greenland Eocene flora consists of dicotyledonous leaves. Among these we find *Ficus*, but this does not mean that figs were members of this flora. The determination of *Ficus* on Heer's part was only tentative, and he published it with a question mark behind it; moreover, it does not suggest any of the numerous species of *Ficus*, either fossil or recent, with which I am familiar. Among the Greenland Tertiary dicotyledons the following genera predominate: *Populus*, *Salix*, *Alnus*, *Betula*, *Corylus*, *Fagus*, *Quercus*, *Juglans*, *Acer*, *Laurus*, *Andromeda*, *Fraxinus*, *Viburnum*, *Cornus*, *Magnolia*, *Ilex*, *Celastrus*, *Rhamnus*, *Rhus*, and *Crataegus*.

These are all genera that range for greater or less distances into, and some, such as *Populus*, *Salix*, *Alnus*, and *Betula*, range entirely across the cool-Temperate Zone. Any one is, of course, at liberty to call this Greenland Tertiary flora "tropical"—after the most detailed comparison and discussion its original describer did not so consider it, nor do I.

In nearly every case where a Greenland Eocene genus is indicative of conditions warmer than cool-Temperate, as, for example, the genera *Pterospermites*, *Sapindus*, *Zizyphus*, *Colutea*, *Laurus*, and *Dalbergia*, the botanical determinations can, and are, seriously questioned, and all that they can be asserted to mean is that the respective forms are similar to forms from other regions which some one, generally Heer himself, called *Colutea*, *Dalbergia*, etc.

The most northerly known Eocene flora is that described by Heer in the fifth volume of his "Flora Fossilis Arctica" from near Cape Murchison in Grinnell Land. As elaborated by Heer this flora comprised 30 species, but it may well be pointed out that a number of these have no existence outside the literature of paleobotany. Thus

there is a single *Equisetum* instead of two species; the four species of *Feildenia* represent but a single botanical species, of still unknown botanical affinity; the five pines represent a less number of species, and were named by Heer before the old genus *Pinus* was segregated; the two *Phragmites* represent leaf fragments of grasses or sedges, and nothing more definite, and the *Caulinites* is a sedge or grass rootstock, while other leaf fragments are named *Carex*. *Iridium* and *Salix* represent absolutely nothing determinable, as Heer practically admits in his discussion of them; the two species of *Corylus* described represent but a single species, to which what Heer called *Alnus* should also probably be referred; the *Ulmus* is also a *Corylus*, in my opinion; the *Viburnum* is a *Populus*; and the *Tilia* is a *Corylus*. These suggested changes may be merely a matter of opinion, they certainly are my opinions, but the suggested revision is no essential part of my argument.

Revised as suggested in the preceding paragraph, the result is: *Equisetum*, *Feildenia*, *Thuites*, *Taxodium*, *Pinus*, *Abies*, sedge or grass fragments, *Populus*, *Betula*, a variety of *Corylus* leaves, and apparently a fragment of a *Nymphæa* rootstock. Considered in this attenuated form this flora is still remarkable enough. The flora in the immediate vicinity of Cape Murchison under the climatic conditions of the present includes *Carex*, various grasses, and the genera *Salix* and *Vaccinium*. The present isotherms would have to swing 15 to 20 degrees northward to permit the existence of such an Eocene flora as that listed above in Grinnell Land. The dwarf birch of the present reaches the latitude of Grinnell Land in Spitzbergen; and white birches occur north of the Arctic Circle in Europe, Asia, and North America, or within about ten degrees of the Grinnell Land fossil flora.

The significant feature about these Eocene Arctic floras is that they show a comparable northward swing of not alone their northern limits, but also of their southern limits, which in turn is comparable to the northward advance of the Jackson flora that I have considered to be of the same age. The Jackson flora reaches Latitude 37° North. The most similar existing flora to that of the Jackson does not extend above Latitude 26° North, and then only under especially

favorable conditions of situation with respect to warm ocean currents. This is a difference of 11 degrees. The flora of the Jackson was, moreover, a coastal flora, and I have not the slightest doubt but that had the Mississippi embayment extended five degrees farther North, its shores would have been clothed with the same Jackson flora, for at that time similar floras are found in the Paris Basin in Latitude 49° North, in southern England in Latitude 51° North, and along the expanded Mediterranean sea of the Old World.

The southern limit of the contemporaneous "Arctic flora" is about Latitude 45° North in North America (British Columbia), and about 57° North in Europe (Isle of Mull). It seems to me that the essential concordance of these facts is significant, and whatever may be thought of them, it would certainly seem to be difficult for any one to claim that these various Eocene floras mentioned do not show a climatic change in passing northward from the equator toward the pole. Moreover, at present—a time of, in many ways, an abnormal climate in a geologic sense; with rather sharp zoning, although not nearly so sharp as the textbooks would have us believe; a time of almost, if not quite, unprecedented land expansion in the Northern Hemisphere—which I believe expresses a causal relationship; the reliable members of these Eocene Arctic floras range much farther southward than they did in late Eocene time.

That changes in the geographic distribution of land and water might prove sufficient to account for these Eocene Arctic floras is suggested by the climatic influence of the northward drift of warm water in the North Atlantic at the present time; which influence in western Europe and Spitzbergen is a trite fact, familiar to all. If the reader will consult an Isothermal map, and will compare the North Atlantic region with that of Behring Strait, or with the center of Siberia (the latter the present location of the cold pole), the combined influence of the northward drift of warm oceanic water from lower latitudes, and the influence of the relative amounts and geographic position of lands and seas, is seen to be most astonishing.

For example, the January isotherm of -25° C., which is at Behring Strait, is 18 degrees farther North in Baffin Bay, and reaches to the pole itself North of Spitzbergen. The July isotherm of 5° C. (41° F.), which is at Behring Strait, swings 10 degrees farther North

in Baffin Bay, and 15 degrees farther North in western Spitzbergen, and there is a corresponding northward swing over the ocean between Spitzbergen and Nova Zembla.

When the times of widest extension of equable and mild climates in the past are considered—the most conspicuous of which, in post-

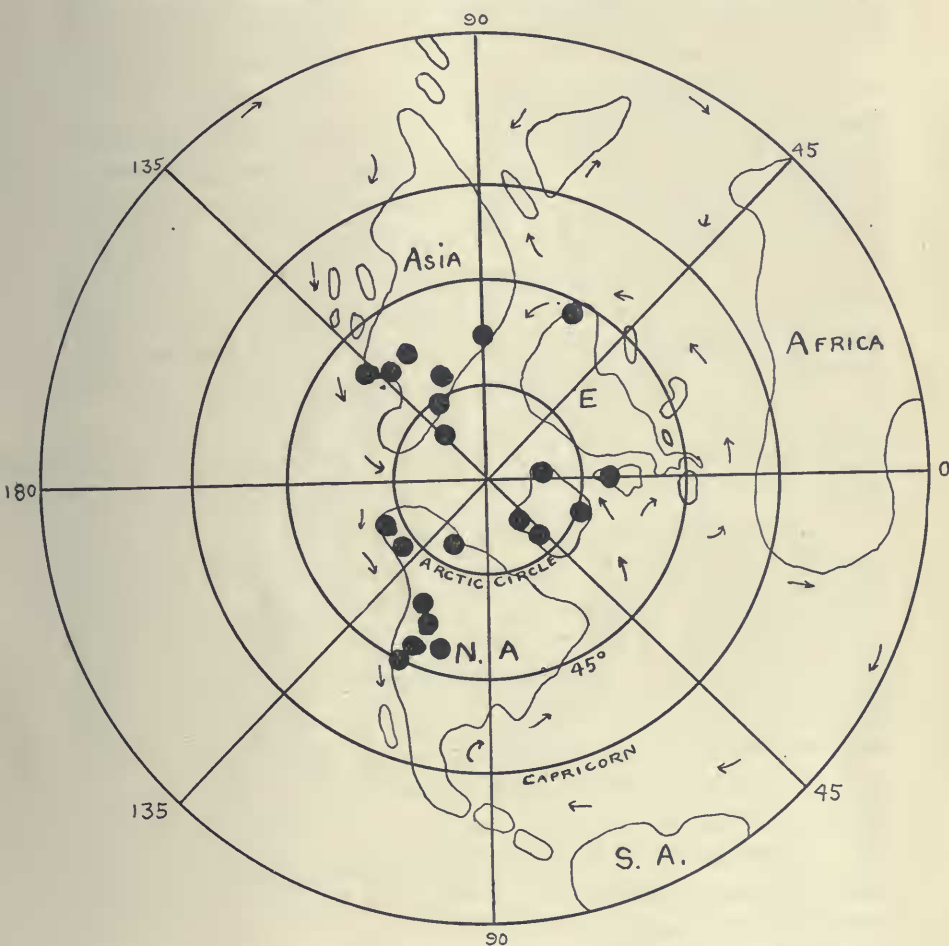


FIG. 1. Sketch map of the middle Eocene showing location of the "Arctic floras" of the upper Eocene.

Paleozoic times, are those of the Jurassic, Cretaceous, and later Eocene—they all appear to bear a definite relationship to periods of sea extension and reduction of land areas. To give objectivity to this statement I have prepared a map, on a North Polar projection,

showing the supposed distribution of land and water in mid-Eocene time.⁴

It will be noted first that the land areas are greatly reduced, amounting to perhaps as much as 40 per cent. of the present land area of the Northern Hemisphere; and their place is taken by mostly shallow seas in low latitudes. The Mediterranean regions of the world are almost continuously under water, and these have free polar connections from the Atlantic, Pacific, and Indian oceans, as well as from the greatly expanded *Tethys*. If the reader will now consult Sir John Murray's quantitative estimates of the present influence of the Gulf stream on western Europe, it will be obvious that a distribution of land and water such as I have indicated for mid-Eocene time would be most important in climatic results. These effects would be cumulative, and, in my opinion, a sufficient cause to account for the observed distribution of the fossil floras of the upper Eocene. That it is a matter of distribution of land and water plus oceanic circulation is indicated by the more northern Eocene distribution of plant types of low latitudes in Europe than in North America, as at the present time.

I would imagine a certain lag in observable effects, due to this cumulative action, and the progressive reduction of polar ice, and the ultimate nullification of appreciable cold ocean currents. I have indicated on the map, in a most general way, the probable directions of the oceanic circulation, as well as the localities where Eocene plants have been found in high latitudes. No one knows exactly what paths a given geographic pattern would impose on definite ocean currents, there being so many factors involved; but certainly no one can object to the statement that the general, or what might be termed the planetary circulation would dominate, except as modified by subordinate and unvaluated factors; or that the northward drift of warm surface waters would be operative.

It will be noted that all of the most northern Eocene plant localities are in coastal situations, favorably situated to receive the full

⁴ This map makes no pretense to accuracy, which is largely a matter of opinion, nor is there anything original about it. It is essentially the map compiled from De Lapparent's "Traité" by W. D. Matthew, and used by H. F. Osborn in his "Age of Mammals."

benefit of this drift of warm oceanic waters, whereas the most southern localities, which here mark the upper Eocene southern limit of alders, birches, hazels, etc., are found at about Latitude 45° North in North America, and fairly well away from coasts in a region where it is reasonable to assume a continental climate may have prevailed, especially if there were mountains intervening, as the textbooks would have us believe.

None of these most southern Eocene floras of the cool-Temperate type come within many degrees of reaching the existing southern limits of their well-determined genera. For example, the hazel (*Corylus*) has its present southern limit at Latitude 31° North, whereas in Eocene time this limit was at about Latitude 45° North. At the time these Temperate types were extending their range northward, almost to the pole itself, warm temperate or sub-tropical types had invaded our Gulf States as well as southern and central Europe.

The conclusion seems probable that the whole world had, at that time, a more or less mild and equable climate, prevailing of the oceanic type, and that the primary cause of this oceanic climate was the diminished and low-lying land areas, and the increased sea areas; so arranged as to permit a maximum of circulation between equatorial and polar regions. The floras show that in spite of this relatively mild and equable climate, then as now, the polar regions were considerably cooler than the equatorial regions. At the present time, because of the great expanse of the Pacific ocean in the equatorial region, its average surface temperature is 19.1° C., as compared with 16.9° C. for the Atlantic and 17° C. for the Indian ocean.

The consensus of opinion that the land masses of the Northern Hemisphere were the main theater of evolution of late Mesozoic and Tertiary terrestrial life, both animal and vegetable, may seem to be opposed to such a free oceanic circulation between the equatorial and polar regions as I have indicated, but this is only an apparent and not a real difficulty. The land emergence whose culmination furnishes geologists with the basis for a boundary between Mesozoic and Cenozoic afforded abundant land paths for the dispersal of terrestrial animals and plants, as witness the essential community of the faunas and floras of early Eocene time throughout the whole of Holarctica.

This time of land connections was followed by sea transgression and land shrinkage, especially pronounced geographically in the middle Eocene (Claiborne-Jackson of the Atlantic Coastal Plain; Lutetian-Auvernian of the French chronology).

During this last period, according to Osborn, the mammalia undergo independent evolution without intercontinental dispersal, and are sharply marked into Palæarctic and Nearctic realms, that are entirely extinct. In Oligocene time land bridges were renewed with community of terrestrial faunas, and not since that time of renewal of intercontinental interchange of species have there been as free water connections between the equatorial and Arctic regions as there were in middle Eocene times. The geographic pattern has fluctuated, to be sure, but as a whole the geography has more nearly approximated that of the present, and this, I believe, was the most important factor in bringing about the climatic facies of the late Tertiary faunas and floras. Nowhere in the North Temperate Zone, as far as I recall, do we find terrestrial faunas or floras, or marine littoral faunas, indicative of as warm conditions in the middle and upper Miocene, or Pliocene, as do those of the later Eocene, and perhaps also those of the early Oligocene.

It is not impossible that some less invoked factor, such as this distribution and attitude of the land and sea, may even account for glacial periods, as Sir Charles Lyell suggested long ago, rather than that these have been the result of causes that are purely speculative, such as sun spots, carbon dioxide, dust, reversal of oceanic circulation, etc. I do not deny that these latter may not have been factors, even major ones, but at the present time they belong, in my judgment, in the same category with that hypothesis which predicates a shifting of the poles.

I fully realize that the facts presented in the foregoing notes by no means solve the difficulties that arise in our endeavors to explain the distribution of organisms in the past, but that they furnish one considerable factor in the uniformitarian interpretation of early Tertiary floral distribution, is my reason for calling attention to the subject in the present brief way.

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April, 1922.